# MiniTK

IBM® version

*Equation Processing Software*
*Disk Inside*

UTS Software

***"The best buy in general scientific software, bar none, ..."***
*T.A.Elkins — Computer Language*

# MiniTK

Software

***"The best buy in general scientific software, bar none, ..."***

*T.A.Elkins — Computer Languag*

### Limitation of Liability

Universal Technical Systems, Inc. (UTS) does not warrant that the software program will function properly in every hardware/software environment. The software may not work in combination with modified versions of the operating system, with certain print-spooling or file facility programs, or with certain printers supplied by independent manufacturers.

Although UTS has tested the software and reviewed the documentation, **UTS makes no warranty or representation, either express or implied, with respect to this software or documentation, including their quality, performance, merchantability, or fitness for a particular purpose. As a result, this software and documentation are licensed "as is," and you, the licensee, are assuming the entire risk as to their quality and performance.**

**In no event will UTS be liable for direct, indirect, special, incidental, or consequential damages arising out of the use or inability to use the software or documentation,** even if advised of the possibility of such damages. In particular, UTS is not responsible for any costs including but not limited to those incurred as a result of lost profits or revenue, loss of use of the computer program, loss of data, the cost of a substitute programs, claims by third parties or for other similar costs.

### Copyright

The UTS documentation and the software are copyrighted with all rights reserved. Under the copyright laws, neither the documentation nor the software may be copied, photocopied, reproduced, translated, or reduced to any electronic medium or machine readable form, in whole or in part, without the prior written consent of UTS, except in the manner described in the **README** file on the program disk.

Copyright © 1988, 1990 Universal Technical Systems, Inc.
1220 Rock Street
Rockford, IL 61101 U.S.A.
(815)-963-2220
Fax (815)-963-8884

All rights Reserved. First edition printed1989. Printed in the United States.

Following is a list of Trademarks ™ of Registered Trademarks ® and the companies by which they are owned:

TK Solver Plus, TKPlus, TK!Solver, TK Solver, TK, MiniTK, Roark & Young on TK, Heat Transfer on TK, Gear Design on TK, TK/CAD Link and MathLook by UTS.

IBM by International Business Machines Corporation
Macintosh by Apple Computer, Inc.

# Table of Contents


Introduction 5
What is MiniTK? 5
Who can benefit from using MiniTK? 5
MiniTK vs. TK Solver Plus 6
**Quick Start** 7
Most Used Commands 7
Sample Problems (filename in parenthesis) 9
1. Basic Math 9
Dimensions of a Cone (CONE) 9
Ladder Puzzle (LADDER) 12
Carpet Roll Analysis (CARPET) 15
2. Introductory Science 16
Acids and Bases (PH) 16
Blood Alcohol Levels (BAC) 19
3. Finance 22
Loan Calculations (LOAN) 22
Mortgage Calculations (MORTGAGE) 25
Return on Investment (ROI) 28
4. Mechanical Engineering 30
Mohr's Circle (MOHR) 30
Elastic Torsion Beam (TORSION) 33
Helical Spring Design (SPRING) 35
5. Electrical Engineering 38
Resistors in Parallel (RESISTOR) 38
6. Heat Transfer Analysis 40
Cylindrical Wall (CYLHEAT) 40
7. Building Design and Construction 42
Stair Design (STAIRS) 42
How to... 45
UTS Family of Software Products 51

# Introduction

## What is MiniTK?

If this is MiniTK then is there a TK? Of course! Here is the rest of the story. MiniTK is a much smaller version of a software product called TK Solver Plus (TK stands for Tool Kit). It is an excellent tool kit for problem solving the creative way. TK has been around since 1983 and is being used by well over 100,000 professionals.

MiniTK can solve problems which have up to 24 equations. It solves problems forward or backward without having to re-write any of the equations (this is called **backsolving**). All you do is type in the equations just as you see them in a text book and you get answers immediately. MiniTK even handles problems which have to be solved iteratively. MiniTK helps you in automatically converting units — inches to meters, kilograms to pounds, Dollars to Yen, ....

## Who can benefit from using MiniTK?

If your work involves solving problems in engineering, science, mathematics, statistics, accounting, finance, banking, real estate, etc., then you need MiniTK.

You Choose the Answer
and
MiniTK Shows You
How to Get it!

# *MiniTK vs TK Solver Plus*

## MiniTK

Equation Solver
Automatic Iterative Solving
Automatic Unit Conversions
On-Line Help
Loading and Saving Models
Print Data From Sheets
50+ Built-In Functions
24 Equations/32 Variables

## TK Solver Plus

Equation Solver
Automatic Iterative Solving
Automatic Unit Conversions
On-Line Help
Loading and Saving Models
Print Data From Sheets
70+ Built-In Functions
**No Limit on Number of Equations**
**On-Line Graphics:**
**Line, Bar, & Pie Charts**
**Plotter and Printer Drivers**
**Data Tables**
**Numeric Formatting**
**User-Defined Functions**
**Unlimited Expandability**
**Import & Export of Data List**
**Ready-to-Use Models:**
**Differentiation**
**Integration**
**Statistics**
**Curve-Fitting**
**Differential Equations**
**Matrix Algebra**
**Complex Numbers**
**3-D and Contour Graphs**
**etc.**

# Quick Start

- Run MiniTK: Type MINITK and press the Enter key
- Load a model by pressing F3
- When MiniTK asks for a filename, press Enter.
- Select the model (filename) of interest to you with the up- and down-arrow keys, and press Enter
- Solve the model by pressing F9
- See the Sample Problems section in this manual for further assistance on the chosen model

# Most-Used Commands

| Command | Effect |
|---|---|
| F1 or ? | Context-Sensitive Help |
| F2 | Cancel |
| Ctrl-Break | Stop Solution Process |
| F3 | Load Model |
| F4 | Save Model |
| F5 | Edit a Field |
| F9 | Solve Model |
| > | Dive Into a Subsheet |
| < | Return from a Subsheet |
| ; | Switch Window |
| = | Select Sheet |
| / | Commands |

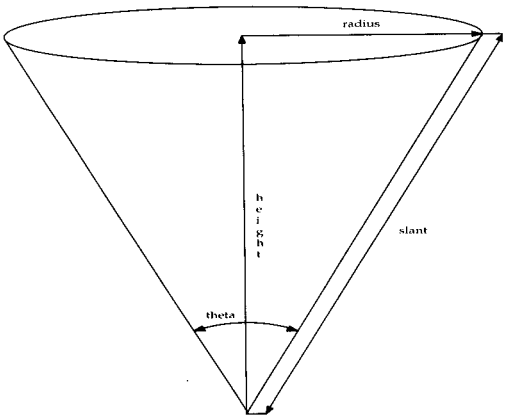
**Need help? Refer to the How To... section or the on-line Help with F1.**

# Sample Problems

## 1. Basic Math

### Dimensions of a Cone

This model solves for the remaining characteristics of a cone when the values of any two are supplied.




### Sample Problem 1-1

The radius of a cone is 3 and its height is 8.5. What are the remaining dimensions?

### Solution

- Load the model CONE
- Enter input values

| | |
|---|---|
| 3 | radius |
| 8.5 | height |

- Solve the model. Answers appear in the output column.

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         CONE MODEL

             volume  80.110613 in^3      volume of the cone
   3         radius             in       radius of opening
   8.5       height             in       vertical height
             surface 84.9538    in^2     outer surface area
             slant   9.0138782 in        length down a side
             theta   38.88007  deg       angle of opening

============================== RULE SHEET ======================================
S Rule ------------------------------------------------------------------------
* volume = 1/3 * pi() * radius^2 * height
* surface = slant * pi() * radius
* slant^2 = height^2 + radius^2
* theta/2 = atand(radius/height)

  "Cone solves for the remaining characteristics of a cone
  "       when the values of any two are supplied.
```

## Sample Problem 1-2

We have been given the following specifications: slant = 8.75 and volume = 80. What are the other parameters of this cone?

## Solution

- Enter input values
  8.75 slant
  80 volume

- Blank the input values of radius and height

- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input---┐ Name--- Output--- Unit----- Comment-------------------------------
                                         CONE MODEL

   80        volume             in^3     volume of the cone
             radius             in       radius of opening
             height             in       vertical height
             surface            in^2     outer surface area
   8.75      slant              in       length down a side
             theta              deg      angle of opening
```

No solution. Since both radius and height appear in the last two equations, the Direct Solver cannot solve the problem directly. Therefore, we need to invoke the Iterative Solver by making one of the unknown variables, a Guess variable.

- Enter input value
  3 radius

- Make radius a Guess variable by entering G in the Status field

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                        CONE MODEL

   80        volume             in^3     volume of the cone
 G 3         radius             in       radius of opening
             height             in       vertical height
             surface            in^2     outer surface area
   8.75      slant              in       length down a side
             theta              deg      angle of opening
```

- Solve the model

```
==================== VARIABLE SHEET ============================================/
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                        CONE MODEL

   80        volume             in^3     volume of the cone
             radius  3.0522012  in       radius of opening
             height  8.2004005  in       vertical height
             surface 83.901762  in^2     outer surface area
   8.75      slant              in       length down a side
             theta   40.830682  deg      angle of opening
```

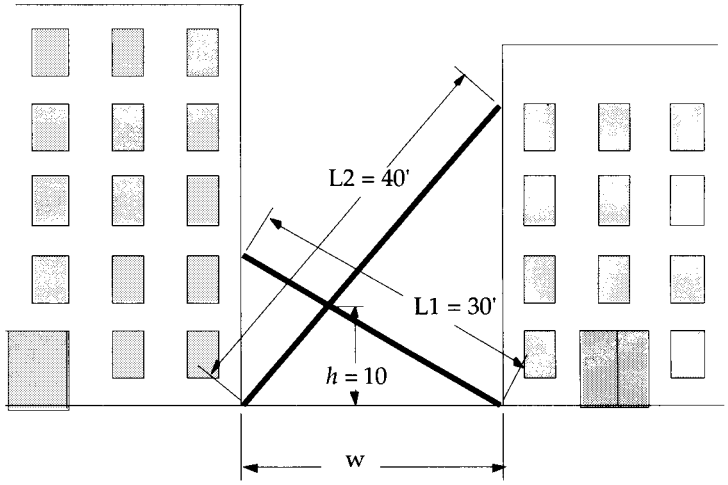
The Iterative Solver returns a value of 3.0522012 for the radius, using 3 as an initial guess value.

## Ladder Puzzle

This application emphasizes the use of the Iterative Solver.

### Sample Problem 1-3

Two ladders lean across an alley in opposite directions. The lengths of the two ladders are 40 and 30 feet and they cross paths at 10 feet in the air. What is the width of the alley?




### Solution

- Load the model LADDER
- Enter input values

| | |
|---|---|
| 10 | h |
| 40 | L1 |
| 30 | L2 |

When TK starts to solve the model, the Direct Solver cannot solve the problem directly by substitution. So, TK uses the Iterative Solver. For the Iterative Solver to work, a variable must be given a guess value.

This model has already supplied the variable w0 with a guess value in its Variable subsheet.

```
==================== VARIABLE: w0 ================================================
Status:
First Guess:        1
Input Value:
Output Value:       .96869431704132429 4
Display Unit:
Calculation Unit:
Comment:            Final width vs. first guess ratio
```

- Solve the model

```
==================== VARIABLE SHEET ==============================================
St Input---- Name--- Output--- Unit----- Comment-----------------------------------
                                          ****  LADDER  ****
   10        h                          Level of the ladders' cross point
   40        L1                         Length of the 1st ladder
   30        L2                         Length of the 2nd ladder
             ya       30.369216         Level of touch point (1st ladder)
             yb       14.909369         Level of touch point (2nd ladder)
             w        26.032878         Width of the alley
             w0       .96869432         Final width vs. first guess ratio
             hmax     17.142857         Maximum feasible level h


============================== RULE SHEET ========================================
S Rule ----------------------------------------------------------------------------
  "              ********** LADDERS IN THE ALLEY  **********
  L1^2 = w^2 + ya^2    " There is an alley bounded by two high buildings.  Two
  L2^2 = w^2 + yb^2    " ladders, L1 and L2 long, rest in corners and lean
  1/h = 1/ya + 1/yb    " against opposite buildings. What is the width  w  of
                       " the alley, knowing the height h of the crossing point?

  " The Iterative Solver has to be used. Guessing the unknown w usually leads
  " to trouble because the interval of feasible guess values is too narrow.
  " A reasonable guess depends on the magnitude of L1,L2,h; we may write it as

*            w/w0 = sqrt(min(L1,L2)^2 - (1/(1/h-1/max(L1,L2)))^2)

  " and assign w0=1 as the First guess. Now iteration is invoked automatically
  " and always converges to a correct solution for any feasible L1,L2,h.

  1/hmax = 1/L1 + 1/L2  " This protects against trying too large a value for h
  h = min(h,hmax)       " error in this rule indicates contradictory data.
```

## Sample Problem 1-4

If we put the same ladders in a different alley, one that is 9 feet wide, what is the height of the ladders' crossing point?

**Solution**

- Enter input value
  9 w
- Blank the variable h
- Solve the model

```
==================== VARIABLE SHEET ========================================
St Input---- Name--- Output--- Unit----- Comment------------------------------
                                          ****  LADDER  ****
             h       16.501452          Level of the ladders' cross point
   40        L1                         Length of the 1st ladder
   30        L2                         Length of the 2nd ladder
             ya      38.974351          Level of touch point (1st ladder)
             yb      28.618176          Level of touch point (2nd ladder)
   9         w                          Width of the alley
             w0      .85427879          Final width vs. first guess ratio
             hmax    17.142857          Maximum feasible level h
```

The above solution illustrates how easily problems can be backsolved in TK Solver, without having to manipulate the equations.

## Carpet Roll Analysis

This application is used to calculate the amount of linoleum or carpet left on a partially used roll.

### Sample Problem 1-5

Given a roll which has an inner circumference of 14.125 inches, an outer circumference of 35.5 inches, a width of 12 feet and a total of 56 layers of material, how much material is left on the roll?

### Solution

- Load the model CARPET
- Enter input values

| | |
|---|---|
| 56 | n |
| 14 + 1/8 | ic |
| 35.5 | oc |
| 12 | width |

- Solve the model

```
=================== VARIABLE SHEET ============================================
St Input-- Name--- Output--- Unit--- Comment-----------------------------------
                                          ** Carpet **
   56      n                          number of "rings" on the roll
   14.125  ic                 in      inner circumference (of the core)
           id      4.4961271  in      inner diameter (of the core)
   35.5    oc                 in      outer circumference
           od      11.300001  in      outer diameter
           length  115.79167  ft      length of remaining linoleum/carpet
   12      width              ft      width of the roll
           sqft    1389.5     ft^2    remaining carpet area

============================== RULE SHEET ====================================
S Rule ------------------------------------------------------------------------
  "   ****  LENGTH OF LINOLEUM OR CARPET REMAINING ON A ROLL  ****

  length = n * (ic + oc) / 2          " This rule uses circumferences
  length = n * pi() * (id + od) / 2   " This rule uses diameters
  ic = pi() * id
  oc = pi() * od
  sqft = width * length

  " The number of "rings" is counted and multiplied by the average
  " length (circumference) of the "rings".  Thickness of the material
  " doesn't need to be known.
```

Try backsolving this problem by blanking the input value of oc, entering 110 as an input value for length, and then solving the problem.

# 2. Introductory Science

## Acids and Bases

This application can be used to examine the relation between pH and concentration of $H^+$ for an arbitrary solution or to analyze situations in which a pure solute made up of a single compound is dissolved in pure water. (Because the small concentration of ions present in water, before the solute is added, is ignored, results given by this model are accurate for strong acids and bases only.)

## Sample Problem 2-1

How many grams of calcium hydroxide, Ca(OH)2, must be added to a liter of pure water to make a solution with a pH of 10?

## Solution

First determine the necessary ion concentration for a pH of 10.

- Load the model PH
- Enter input value
  10 pH
- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input-- Name--- Output--- Unit--- Comment-------------------------------------
   10      pH                      pH
           concH     1E-10   mole/L  H+ ion concentration
           pOH       4               pOH
           concOH    .0001   mole/L  OH- ion concentration
           V                 L       volume of solution
           gmm               g/mole  gram-molecular mass of solute
           m_acid            g       mass of acid solute added
           m_base            g       mass of base solute added
           n_acid            mole    moles of acid solute
           n_base            mole    moles of base solute
           H_ion                     moles of H+ released per mole of solution
           OH_ion                    moles of OH- released per mole of solution
           mlr_aci           mole/L  molarity of acid solution
           mlr_bas           mole/L  molarity of base solution
```

```
============================== RULE SHEET ====================================
S Rule ------------------------------------------------------------------------
  1E-14 = concH*concOH   "product of [H+] and [OH-] is ionization const. of H2O
  pH  = -log(concH)
  pOH = -log(concOH)
  n_acid = m_acid/gmm
  n_base = m_base/gmm          " PH.TK  calculates the values used when
  concH  = n_acid*H_ion/V      " dealing with 'strong' acids and bases.
  concOH = n_base*OH_ion/V
  mlr_acid = n_acid/V
  mlr_base = n_base/V
```

Ca(OH)2 is a base that releases two OH- ions per molecule when dissolved in water. Its gram-molecular mass is approximately equal to the sum of the gram-molecular masses of the atoms which make up the molecule. To solve for the mass of Ca(OH)2:

- Enter input values

| | |
|---|---|
| 1 | V |
| 40.08+(15.9994+1.0079)*2 | gmm |
| 2 | OH_ion |

- Solve the model

Note: Values can be entered in MiniTK in the form of an expresssion as shown above.

```
=================== VARIABLE SHEET ====================================
St Input-- Name--- Output--- Unit--- Comment-----------------------------
                                       ** ACIDS AND BASES **
   10      pH                         pH
           concH    1E-10     mole/L  H+ ion concentration
           pOH      4                 pOH
           concOH   .0001     mole/L  OH- ion concentration
   1       V                  L       volume of solution
   74.0946 gmm                g/mole  gram-molecular mass of solute
           m_acid             g       mass of acid solute added
           m_base   .00370473 g       mass of base solute added
           n_acid             mole    moles of acid solute
           n_base   .00005     mole    moles of base solute
           H_ion                      moles of H+ released per mole of V
   2       OH_ion                     moles of OH- released per mole of V
           mlr_aci            mole/L  molarity of acid solution
           mlr_bas  .00005    mole/L  molarity of base solution
```

The solution indicates that approximately 0.0037 grams of Ca(OH)2 must be added for a pH of 10.

## Sample Problem 2-2

A solution is made from 1 gram of hydrogen chloride (HCL) and 1500 milliliters of water. What is the pH?

## Solution

Each molecule of HCL releases one hydrogen ion into solution. It's gram-molecular mass of solute, is the sum of the atomic masses of its component atoms.

- Enter input values

  | | |
  |---|---|
  | 1.5 | V |
  | 1.0079+35.453 | gmm |
  | 1 | m_acid |
  | 1 | H_ion |

- Blank the input values for pH and OH_ion
- Change the unit for V to ml
- Solve the model

```
=================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment------------------------------
                                         ** ACIDS AND BASES **
             pH      1.7379186           pH
             concH   .01828443 mole/L    H+ ion concentration
             pOH     12.262081           pOH
             concOH  5.469E-13 mole/L    OH- ion concentration
   1500      V                 ml        volume of solution
   36.4609   gmm               g/mole    gram-molecular mass of solute
   1         m_acid            g         mass of acid solute added
             m_base            g         mass of base solute added
             n_acid  .02742664 mole      moles of acid solute
             n_base            mole      moles of base solute
   1         H_ion                       moles of H+ released/mole of so
             OH_ion                      moles of OH- released/mole of s
             mlr_aci .01828443 mole/L    molarity of acid solution
             mlr_bas           mole/L    molarity of base solution
```

So the required pH level is found to be 1.7379186.

## Blood Alcohol Levels

This model estimates the alcohol concentration in the blood of an individual who has consumed alcoholic beverages.

The significance of BAC for this application:

| | |
|---|---|
| .05 or less | not drunk |
| .05 < BAC < .10 | questionable – test further |
| .10 or greater | drunk |

Since the rate of dissipation varies between individuals, the average rate of .018 is used for the sample problems.

### Sample Problem 2-3

This model is initially set for a 200lb person who consumed 6 shots of 86 proof whiskey and 6 12oz bottles of domestic beer in 5 hours.

### Solution

- Load the model BAC
- The inputs are already input for you
- Solve the model

```
=================== VARIABLE SHEET ============================================
St Input---- Name--- Output---Unit--- Comment---------------------------------
             finalBA .11475   %      BAC after elapsed time,0.1+ = drunk
   200       weight           lbs    body weight
   6         shots                   number of 1 oz shots of whiskey
   6         bottles                 number of bottles of beer
   12        size             oz     size of the beer bottle
   5         time             hr     hours since first drink
   43        paw              %      % of alcohol in whiskey : proof/2
   4         pab              %      % of alcohol in beer : average = 4
             BACb     .108    %      Alcohol concentration from beer
             BACw     .09675  %      Alcohol concentration from whiskey
             BAC      .20475  %      Total Blood alcohol concentration
   .018      disrate          1/hr   rate of dissipation
```

```
================================ RULE SHEET ==========================================
S Rule ------------------------------------------------------------------------------
  BACb = (150/weight)*(pab/50)*bottles*size*.025  "Blood alcohol conc. for beer
  BACw = (150/weight)*(paw/50)*shots*.025         "Blood alcohol conc. for whiskey
  BAC = BACb + BACw                               "Total BAC
  finalBAC = BAC - disrate*time                   "BAC after time

  " This model is set up for a 200lb person who consumed 6 shots
  " of 86 proof whiskey and 6 12oz bottles of beer within 5 hours.
  " BAC will determine his final blood alcohol concentration after time
  " When you solve you will find his finalBAC is more than 0.1. He is drunk.

  " TK flexibility: one can find out how long he has to stay before
  " he can drive after consuming so much, or how much he can consume if
  " he needs to drive away after a certain period of time.
```

This person should not drive now. How long should he wait?

- Enter input value
  .05 finalBAC
- Blank the input value for time
- Solve the model

The value given for time is the total time elapsed since the first drink.

```
=================== VARIABLE SHEET ================================================
St Input--- Name--- Output-- Unit-----Comment---------------------------------------
   .05      finalBA          %       BAC after elapsed time,0.1+ = drunk
   200      weight           lbs     body weight
   6        shots                    number of 1 oz shots of whiskey
   6        bottles                  number of bottles of beer
   12       size             oz      size of the beer bottle
            time   8.5972222 hr      hours since first drink
   43       paw              %       % of alcohol in whiskey : proof/2
   4        pab              %       % of alcohol in beer : average = 4
            BACb   .108      %       Alcohol concentration from beer
            BACw   .09675    %       Alcohol concentration from whiskey
            BAC    .20475    %       Total Blood alcohol concentration
   .018     disrate          1/hr    rate of dissipation
```

## Sample Problem 2-4

A person weighing 150lbs has 3 hours to spend relaxing at a friend's house before he can drive. How much can he drink at his friend's house and not test drunk.

## Solution

- Enter input values

| | |
|---|---|
| .05 | FinalBAC |
| 150 | weight |
| 0 | shots |
| 3 | time |

- Blank the input value for bottles
- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input--- Name--- Output--Unit--- Comment-----------------------------------
   .05      finalBA          %       BAC after elapsed time,0.1+ = drunk
   150      weight           lbs     body weight
   0        shots                    number of 1 oz shots of whiskey
            bottle 4.3333333          number of bottles of beer
   12       size             oz      size of the beer bottle
   3        time             hr      hours since first drink
   43       paw              %       % of alcohol in whiskey : proof/2
   4        pab              %       % of alcohol in beer : average = 4
            BACb    .104     %       Alcohol concentration from beer
            BACw    0        %       Alcohol concentration from whiskey
            BAC     .104     %       Total Blood alcohol concentration
   .018     disrate          1/hr    rate of dissipation
```

Drinking 4 1/3 bottles of beer over 3 hours results in a BAC level of .05.

# 3. Finance

## Loan Calculations

This application is used to determine the dollar value of the payments necessary to repay a particular loan, or the dollar value of the loan which can be repaid by a particular payment.

### Sample Problem 3-1

A car is being purchased for $15,500 with a down payment of $3,500. How much will the payments be for the next 5 years with an interest rate of 10.5%?

### Solution

- Load the model LOAN
- Enter input values

| | |
|---|---|
| 15500 | price |
| 3500 | downpay |
| 10.5 | rate |
| 5 | term |

- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         ***  LOAN  CALCULATIONS ***
  15500      price             $         total price
   3500      downpay           $         down payment
             loan     12000    $         loan amount
             payment  257.9268 $/mo      monthly payment
    10.5     rate              %/yr      interest rate
    5        term              yr        loan term


================================ RULE SHEET ====================================
S Rule ----------------------------------------------------------------------
  price - downpay = loan
  payment = loan * (rate / (1 - (1 + rate)^(-term)))

  " N o t e :
  " The simplicity and the utility of this model makes it
  " an ideal vehicle for explaining the basic concepts of
  " TK design and operation
```

Unfortunately, $250 is the maximum affordable payment at this time. What interest rate would be necessary to have payments of this amount.

- Enter input value
  250 payment

- Make rate a Guess variable by entering G in the Status field

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         ***  LOAN  CALCULATIONS ***
   15500     price             $         total price
   3500      downpay           $         down payment
             loan    12000     $         loan amount
   250       payment           $/mo      monthly payment
 G 10.5      rate              %/yr      interest rate
   5         term              yr        loan term
```

- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         ***  LOAN  CALCULATIONS ***
   15500     price             $         total price                          /
   3500      downpay           $         down payment
             loan    12000     $         loan amount
   250       payment           $/mo      monthly payment
             rate    9.1543234 %/yr      interest rate
   5         term              yr        loan term
```

In order to make the monthly payment equal to $250, the interest rate has to be lowered from 10.5% to 9.15%. Now, just find a bank who will offer that interest rate!

## Sample Problem 3-2

A recent graduate, who needs a car, can afford car payments of $125 over the next 3.5 years. He also has $700 for a downpayment. If the going interest rate is 9%, how expensive a car can he buy?

## Solution

- Enter input values

| | |
|---|---|
| 700 | downpay |
| 125 | payment |
| 9 | rate |
| 3.5 | term |

- Blank the input value for price

- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment------------------------------
                                         *** LOAN CALCULATIONS ***
           price   5189.2141 $          total price
   700     downpay           $          down payment
           loan    4489.2141 $          loan amount
   125     payment           $/mo       monthly payment
   9       rate              %/yr       interest rate
   3.5     term              yr         loan term
```

Note: The automatic unit conversion capability of MiniTK can be used to display results in dollars, British Pounds, French francs, German Marks, Japanese Yens, etc. An example Unit Sheet is shown below.

```
==================== UNIT SHEET ================================================
From    To         Multiply By          Add Offset Comment
$       Pound      1.6
$       Yen        150
$       FrFranc    5.75
$       DM         1.7
```

The above problems illustrate again how powerful, but yet easy to use, the backsolving capability of TK Solver is.

## Mortgage Calculations

This application is used to determine the maximum cost of a house that can be afforded given a certain salary and loan components, or the salary necessary to afford a house at a certain price.

### Sample Problem 3-3

Given an income of $35,000/yr which lands in the 33% tax bracket, what is the most expensive house which can be mortgaged for 25 yrs at 10.5% when personal savings used as a down payment equals $8,000.

### Solution

- Load the model MORTGAGE

- Enter input values

| | |
|---|---|
| 35000 | salary |
| 33 | bracket |
| 8000 | onhand |
| 25 | term |
| 10.5 | rate |
| 70000 | house (entered as a Guess variable) |

- Make house a Guess variable by entering G in the Status field (if G is not entered already)

- Solve the model

```
==================== VARIABLE SHEET ========================================
St Input-- Name---- Output---Unit---- Comment--------------------------------
                                      ******** MORTGAGE MODEL
   35000   salary            $/yr     salary
   33      bracket           %        income tax bracket
   8000    onhand            $        cash for closing costs, down pymt
   25      term              yr       term of mortgage
   10.5    rate              %/yr     interest rate
           house   79389.56  $        maximum house price you can afford
           loan    73356.694 $        maximum mortgage allowed by bank
           closing 1967.1339 $        closing costs
           downpay 6032.8661 $        down payment
           dp%     7.5990674 %        down payment percentage
           payment 692.62048 $/mo     periodic mortgage payment
           tax     124.04619 $/mo     property tax
           pit     816.66667 $/mo     principal + int + property tax
           savings 188.80764 $/mo     periodic income tax savings
           netpymt 627.85903 $/mo     periodic payment with tax savings
           Tp      207786.14 $        total amount paid over term
           Tip     134429.45 $        total interest payments over term
```

```
============================== RULE SHEET ==================================
S Rule ----------------------------------------------------------------------
       "     ****  Rule Sheet for "MORTGAGE" model     ****
  closing = .02*loan + 500       " # # # # # # # # # # # # # # # # # # # # "
  pit = .28*salary               " According to the 1987 Tax Law, property tax "
  onhand = downpay + closing     " is no longer deductible, so for 1987 the    "
  tax = .025*.75*house/12        " savings = ... equation should be modified.  "
  house = loan + downpay         " # # # # # # # # # # # # # # # # # # # # "
  downpay = house*dp%
  payment = loan*(rate/(1 - (1 + rate)^-term))
  Tp = payment*term
  Tip = Tp - loan
  savings = bracket*(tax + payment*Tip/Tp)  "/ average savings and netpymt
  netpymt = pit - savings                   "\    over the term of loan
  pit = payment + tax          " i.e., .28*salary = f(loan,rate,term) + f(house)

  " Note: The model lets you find how expensive a house you can buy given the
  "       salary, loan terms, etc.; how much you need to earn to buy a certain
  "       house; and so on.  In the 1st case you have to guess the house price.
```

Now let's turn the problem around and find out the salary necessary to pay for a $100,000 house within 30 years.

- Make salary a Guess variable by entering G in the Status field

- Enter input value

  30 term

  100000 house

```
==================== VARIABLE SHEET ========================================
St Input-- Name--- Output--- Unit---- Comment---------------------------------
                                      ******* MORTGAGE MODEL
 G 35000    salary           $/yr     salary
   33       bracket          %        income tax bracket
   8000     onhand           $        cash for closing costs,down pymt
   30       term             yr       term of mortgage
   10.5     rate             %/yr     interest rate
   100000   house            $        maximum house price you can afford
```

- Solve the model

```
==================== VARIABLE SHEET ========================================
St Input-- Name--- Output--- Unit---- Comment---------------------------------
           salary  43699.367 $/yr     salary
   33      bracket           %        income tax bracket
   8000    onhand            $        cash for closing costs,down payment
   30      term              yr       term of mortgage
   10.5    rate              %/yr     interest rate
   100000  house             $        maximum house price you can afford
           loan    94387.755 $        maximum mortgage allowed by bank
           closing 2387.7551 $        closing costs
           downpay 5612.2449 $        down payment
           dp%     5.6122449 %        down payment percentage
           payment 863.40189 $/mo     periodic mortgage payment
           tax     156.25    $/mo     property tax
           pit     1019.6519 $/mo     principal + interest + property tax
           savings 249.96301 $/mo     periodic income tax savings
           netpymt 769.68887 $/mo     periodic payment with tax savings
           Tp      310824.68 $        total amount paid over term
           Tip     216436.92 $        total interest payments over term
```

What's left to do, is to ask the boss for a raise from $35,000/year to $43,700/year.

## Return on Investment

This model calculates the net present value and internal rate of return of a stream of cash flows.

## Sample Problem 3-4

You want to calculate the internal rate of return for a $990 equipment acquisition over a period of 4 months. You estimated that you could save $250 in the first month, $500 in the second, $250 in the third, and $50 in the fourth.

## Solution

- Load the model ROI
- Enter input values

| | |
|---|---|
| 990 | NPV |
| 250 | c1 |
| 500 | c2 |
| 250 | c3 |
| 50 | c4 |

- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         ***** Return on Investment **
   990       NPV                         Net Present Value
             r                 %/yr      Rate of Return
   250       c1                          Cash Flow in 1st Period
   500       c2                          Cash Flow in 2nd Period
   250       c3                          Cash Flow in 3rd Period
   50        c4                          Cash Flow in 4th Period

============================== RULE SHEET ======================================
S Rule -----------------------------------------------------------------------
  NPV = c1/(1+r) + c2/(1+r)^2 + c3/(1+r)^3 + c4/(1+r)^4
```

No solution — because the variable r appears more than once in the equation; therefore, you have to give r a guess value.

- Make r a Guess variable by entering G in the Status field

- Solve the model

```
==================== VARIABLE SHEET ====================================
St Input     Name    Output     Unit      Comment
                                          ***** Return on Investment ****
   990       NPV                          Net Present Value
             r       34.330895 %/yr       Rate of Return
   250       c1                           Cash Flow in 1st Period
   500       c2                           Cash Flow in 2nd Period
   250       c3                           Cash Flow in 3rd Period
   50        c4                           Cash Flow in 4th Period
```

What if you wanted the rate of return to be exactly 30%, and you wanted to know the cash flow in the first month?

## Solution

- Enter input value
  30 r

- Blank the input value for c1

- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         ***** Return on Investment *****
   990       NPV                         Net Present Value
   30        r                  %/yr     Rate of Return
             c1      242.56155           Cash Flow in 1st Period
   500       c2                          Cash Flow in 2nd Period
   250       c3                          Cash Flow in 3rd Period
   50        c4                          Cash Flow in 4th Period
```

Before going on to the next sample problem, try entering 300 as an input value for c1, blank the input value of NPV, and then solve again.

# 4. Mechanical Engineering

## Mohr's Circle

This model uses a Mohr's circle representation of stress to determine maximum axial and shear stresses, the axes on which they lie and combined stresses at any plane of orientation. The value of the stresses and the orientation of the element can be manipulated so that the model can handle any combination of stresses acting on a two-dimensional element.

Mohr's circle is only valid for two-dimensional states of stress. Positive angles represent counter-clockwise rotation. Note that an angle on the Mohr's circle is double the corresponding angle in the actual physical case.

### Sample Problem 4-1

An element is subjected to tensile stress Sx = 110 psi, tensile stress Sy = 50 psi, and shear stress Txy = 40 psi. What are the corresponding values Sx', Sy' and Tx'y' if the reference axes are rotated 45 degrees (represented by 90 degrees on the circle)? Also, what are the values of the principal stresses and how are they oriented with respect to the original reference axes?

### Solution

- Load the model MOHR
- Enter input values

| | |
|---|---|
| 110 | Sx |
| 50 | Sy |
| 40 | Txy |
| 45 | theta |

- Solve the model

```
==================== VARIABLE SHEET ========================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         **  Mohr's Circle for Stress  **

   110       Sx                 psi       normal stress, x-directed
   50        Sy                 psi       normal stress, y-directed
   40        Txy                psi       shear stress in xy plane
   45        theta              deg       angle between x and x' axes

             Sx`      120       psi       normal stress, x'-directed
             Sy`      40        psi       normal stress, y'-directed
             Tx`y`    -30       psi       shear stress in x'y' plane

             S1       130       psi       maximum principal stress
             S2       30        psi       minimum principal stress
             Tmax     50        psi       maximum shear stress

             theta1   26.565051 deg       angle, x axis to plane of S1
             theta2   -63.43495 deg       angle, x axis to plane of S2
             theta3   71.565051 deg       angle, x axis to plane of Tmax

                                         Mohr's Circle parameters:
             r        50        psi         radius
             c        80        psi         distance, origin to center
             twoth1   53.130102 deg         angle, xy plane to sigma-axis
             twoth    90        deg         angle, xy plane to x'y' plane

                                         intermediate variables:
             A        80        psi         (Sx+Sy)/2
             B        30        psi         (Sx-Sy)/2
             C        40        psi         Txy

==================== RULE SHEET ============================================
S Rule-------------------------------------------------------------------------
  A=(Sx+Sy)/2
  B=(Sx-Sy)/2
  C=Txy
  S1=A+sqrt(B^2+C^2)
  S2=A-sqrt(B^2+C^2)
  Tmax=r
  theta1=atan2(C,B)/2
  if theta1>0 then theta2=theta1-pi()/2 else theta2=theta1+pi()/2
  theta3=theta1+pi()/4
  twoth=2*theta
  twoth1=2*theta1
  Sx`=A+B*cos(twoth)+C*sin(twoth)
  Sy`=A-B*cos(twoth)-C*sin(twoth)
  Tx`y`=-B*sin(twoth)+C*cos(twoth)
  c=A
  r^2=B^2+C^2
```

Now find the angle the reference axes must be rotated in order for the new y-directed stress to equal 100 psi.

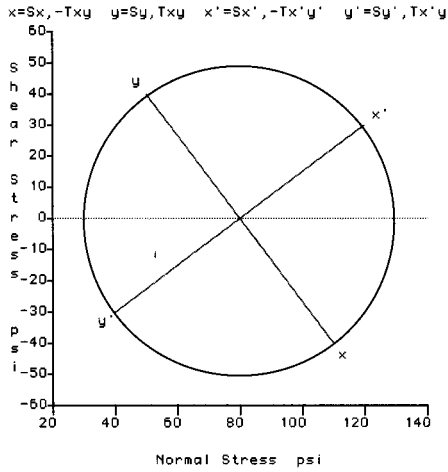
- Enter input values
  100 Sy'

- Make theta a guess variable by entering a G in its Status field

- Solve the model

```
=================== VARIABLE SHEET ========================================
St Input---- Name--- Output--- Unit------ Comment------------------------------
                                         **  Mohr's Circle for Stress  **

   110       Sx                 psi       normal stress, x-directed
   50        Sy                 psi       normal stress, y-directed
   40        Txy                psi       shear stress in xy plane
             theta    83.35414  deg       angle between x and x' axes

             Sx`      60        psi       normal stress, x'-directed
   100       Sy`                psi       normal stress, y'-directed
             Tx`y`    -45.82576 psi       shear stress in x'y' plane

             S1       130       psi       maximum principal stress
             S2       30        psi       minimum principal stress
             Tmax     50        psi       maximum shear stress

             theta1   26.565051 deg       angle, x axis to plane of S1
             theta2   -63.43495 deg       angle, x axis to plane of S2
             theta3   71.565051 deg       angle, x axis to plane of Tmax

                                         Mohr's Circle parameters:
             r        50        psi         radius
             c        80        psi         distance, origin to center
             twoth1   53.130102 deg         angle, xy plane to sigma-axis
             twoth    166.70828 deg         angle, xy plane to x'y' plane

                                         intermediate variables:
             A        80        psi         (Sx+Sy)/2
             B        30        psi         (Sx-Sy)/2
```

The required angle between x and x' is then found to be 83.35414 degrees.



## Elastic Torsion Beam

This application analyses the pure elastic torsion of a cylindrical beam. It involves linear elastic torsion of cylindrical sections and can be used to calculate the polar moment of inertia for circular cross-sections, the maximum material stress at the outside surface of a beam, and the angular deflection or twist displacement at the beam tip. Beam dimensions, applied torques, and internal stresses are combined to solve a wide variety of torque problems.

## Sample Problem 4-2

A torque of 300 inch-pounds is applied at the end of an 8-inch long solid cylindrical rod .5 inch in diameter, the other end of which is fixed. The alloy of which the rod is made has an elastic shear modulus of 1.1 * 10^7 lb/in^2. Find phi, the angle of twist.

## Solution

- Load the model TORSION
- Enter input values

| | |
|---|---|
| 300 | torque |
| 8 | L |
| .5 | D |
| 0 | d |
| 1.1E7 | G |

- Solve the model

```
=================== VARIABLE SHEET ============================================
St Input--- Name-- Output-- Unit-----Comment-----------------------------------
                                    ** ELASTIC TORSION BEAM **
   300      torque          in*lb    torque on beam
   8        L               in       length of cylindrical beam
   .5       D               in       outside diameter of torsion beam
   0        d               in       inside diameter of torsion beam
            Ip     .00613592 in^4     polar moment of inertia of section
            Area   .19634954 in^2     cross-sectional area of beam
   11000000 G               lb/in^2  elastic shear modulus
            Smax   12223.1   lb/in^2  shear stress at beam outside surface
            phi    2.0373295 deg      angle of twist
            K      147.25158 in*lb/de torsional spring constant
```

```
============================== RULE SHEET ====================================
S Rule ---------------------------------------------------------------------
  Area = pi()*(D^2 - d^2)/4
  Ip = pi()*(D^4 - d^4)/32
  torque = K*phi
  Smax = torque*D/(2*Ip)
  K = G*Ip/L
 "TORSION is an aid to analysis of pure elastic torsion of
 "a cylindrical beam
```

## Sample Problem 4-3

A 20 inch long titanium tube with a 1 inch outside diameter is used as a torsional spring. The desired spring constant is 500 inch-pounds of torque per degree of twist. Titanium has a shear modulus of 6.0 * 10^6 lb/in^2. Find the required inside diameter of the tube, and the maximum shear stress in the material when the tube is twisted 10 degrees.

## Solution

- Enter input values

| | |
|---|---|
| 20 | L |
| 1 | D |
| 6.0E6 | G |
| 10 | phi |
| 500 | K |

- Blank the input values for torque and d
- Solve the model

```
=================== VARIABLE SHEET ============================================
St Input--- Name-- Output-- Unit---- Comment-----------------------------------
                                     ** ELASTIC TORSION BEAM **
           torque5000       in*lb    torque on beam
   20      L                in       length of cylind beam in torsion
   1       D                in       outside diameter of torsion beam
           d     .4065433   in       inside diameter of torsion beam
           Ip    .09549297  in^4     polar moment of inertia of section
           Area  .65558955  in^2     cross-sectional area of beam
   6000000 G                lb/in^2  elastic shear modulus
           Smax  26179.939  lb/in^2  shear stress at beam outside surface
   10      phi              deg      angular disp. of beam over length L
   500     K                in*lb/de torsional spring constant
```

As can be seen from above, the inside diameter is .4065433", and maximum shear stress is 26179.939 lb/in$^2$.

## Helical Spring Design

This model is an aid in the design of dimensional and material characteristics of helical coil springs in tension or compression.

### Sample Problem 4-4

A helical spring made of round rolled steel, with a shear modulus of 11 x $10^6$ lb/in$^2$, has a wire diameter of 2 inches and a coil radius of 5 inches. It consists of 7 coils, and is loaded in compression by a force of 2200 pounds. What is its spring constant and how far does it compress?

### Solution

- Load the model SPRING
- Enter input values

| | |
|---|---|
| 1 | Rw |
| 5 | Rs |
| 7 | n |
| 11E6 | G |
| 2200 | F |

- Solve the model

```
=================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment------------------------------
                                         **** HELICAL SPRING **********
           error    'none               physical impossibility error message

           tight    'no                 spring tightly coiled?('yes,'no)
   1       Rw                 in        radius of round wire
           Lw       219.91149 in        length of wire
   5       Rs                 in        radius of spring coil
   20      Ls                 in        length of spring
   7       n                            total number of spring coils
           coil     .35       1/in      number of coils per unit length
   11000000 G                 lb/in^2   shear modulus of elasticity
   2200    F                  lb        force acting on spring
           k        3142.8571 lb/in     spring constant
           x        .7        in        displacement: compress/extension
           Sw       7002.8175 lb/in^2   torsional stress in displaced wire
           y        6         in        maximum possible disp. in compression
           Lmin     14        in        length when tightly coiled
```

```
============================== RULE SHEET ========================================
S Rule ------------------------------------------------------------------------
  k=G*Rw^4/(4*Rs^3*n)
  Lw=2*pi()*Rs*n
  coil=n/Ls
  Sw=2*F*Rs/(pi()*Rw^3)
  F=k*x
  y=Ls-Lmin
  Lmin=2*n*Rw

  imposs1=step(Rw,Rs/2)          "imposs1=1 if coil radius<min poss., 0 otherwise
  imposs2=2*(1-step(y,0))        "imposs2=2 if length<min poss., 0 otherwise
  imposs2*given('Ls,0,given('coil,'n,0,1))=0    "imposs2=0 if not enough info.
  imposs=imposs1+imposs2
  if imposs=0 then error = 'none
  if imposs=1 then error = 'overcoiled
  if imposs=2 then error = 'overcompressed
  if imposs=3 then error = 'both_overcoiled_and_overcompressed

  y*tightnum=0                   "set y=0 if tightly coiled
  tightnum=1-abs(sgn(y))         "tightnum=1 if tightly coiled, 0 otherwise
  if tightnum = 0 then tight = 'no
  if tightnum = 1 then tight = 'yes
```

The spring constant is then 3142.8571 lb/in., and the displacement is .7".

## Sample Problem 4-5

If the displacement should be exactly .5 inches when 2200 lb of force are applied, how would that affect the number of spring coils in the spring?

## Solution

- Enter input values
  .5 x
- Blank the input value for n
- Solve the model

```
=================== VARIABLE SHEET ========================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         ***** HELICAL SPRING **********
             error   'none               physical impossibility error message

             tight   'no                 spring tightly coiled? ('yes,'no
   1         Rw                 in       radius of round wire
             Lw      157.07963  in       length of wire
   5         Rs                 in       radius of spring coil
   20        Ls                 in       length of spring
             n       5                   total number of spring coils
             coil    .25        1/in     number of coils per unit length
   11000000  G                  lb/in^2  shear modulus of elasticity
   2200      F                  lb       force acting on spring
             k       4400       lb/in    spring constant
   .5        x                  in       displacement: compression/extension
             Sw      7002.8175  lb/in^2  torsional stress in displaced wire
             y       10         in       maximum possible disp. in compression
             Lmin    10         in       length when tightly coiled
```

In order to reduce the displacement from .7" to .5", the number of coil springs has to be reduced to 5 instead of 7.

# 5. Electrical Engineering

## Resistors in Parallel

This model calculates the total resistance, voltage, current, and power of four resistors in parallel.

### Sample Problem 5-1

Four resistors in parallel are powered by a 12 volt voltage source. If R1 is 50 ohms, R2 is 100, R3 is 75, and R4 is 50 ohms, then calculate the resulting total resistance, current and power.

### Solution

- Load the model RESISTOR
- Enter input values

| | |
|---|---|
| 50 | R1 |
| 100 | R2 |
| 75 | R3 |
| 50 | R4 |
| 12 | V |

- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment------------------------------
                                         **** Resistors in Parallel ***
             R       15.789474           Total Resistance
   50        R1                          Resistor 1
   100       R2                          Resistor 2
   75        R3                          Resistor 3
   50        R4                          Resistor 4
   12        V                           Voltage
             I       .76                 Current
             Power   9.12                Power


============================== RULE SHEET ======================================
S Rule -------------------------------------------------------------------------
  1/R = 1/R1 + 1/R2 + 1/R3 + 1/R4
  V = I * R
  Power = I^2 * R
```

The total current is .76 ampere, total power is 9.12 watts, and the total resistance is 15.789474 Ohms.

## Sample Problem 5-2

If it is required that the current be exactly .7 ampere, then what resistance is required for R2?

## Solution

- Enter input values
  .7 I
- Blank the input value for R2
- Solve the model

```
==================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                         **** Resistors in Parallel ****
             R       17.142857           Total Resistance
   50        R1                          Resistor 1
             R2      200                 Resistor 2
   75        R3                          Resistor 3
   50        R4                          Resistor 4
   12        V                           Voltage
   .7        I                           Current
             Power   8.4                 Power
```

To satisfy the total current requirement of .7 ampere, the resistance of R2 has to be doubled from 100 Ohms to 200 Ohms.

# 6. Heat Transfer Analysis

## Cylindrical Wall

This model is an aid to the analysis of heat transfer from a fluid through a two-layered cylindrical wall to an outside fluid by means of convection, conduction, and radiation.

### Sample Problem 6-1

A 6 inch inside diameter cast iron pipe with a 1/4 inch thick wall is covered with a 1 inch thick layer of molded pipe insulation. The conductive constants of the cast iron and the insulation are 33 Btu/(h-ft-°F) and .051 Btu/(h-ft-°F) respectively. The steam inside the pipe has a convection coefficient of 100 Btu/(h-ft²-°F) at a temperature of 300°F. The room temperature is 120°F with a convection coefficient to the air of 10 Btu/(h-ft²-°F) and an emissivity of .9. What is the heat loss per foot of pipe?

### Solution

- Load the model CYLHEAT

- Enter input values

| | |
|---|---|
| 1 | L |
| 3 | r1 |
| 100 | h1 |
| 33 | k1 |
| 3+1/4 | r2 |
| .051 | k2 |
| 3+1/4+1 | r3 |
| 10 | h2 |
| .9 | epsi |
| 75 | Q (entered as a guess value) |
| 300 | T0 |
| 120 | T4 |
| 1.713E-9 | sigma |

- Make Q a Guess variable by entering G in the Status field (if it isn't there already)

- Solve the model

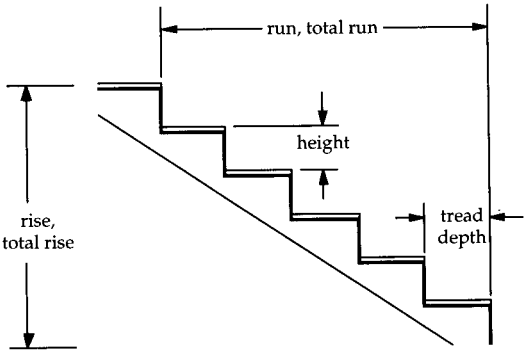
```
===================== VARIABLE SHEET ============================================
St Input---- Name--- Output--- Unit----- Comment-------------------------------
                                        *CYLINDRICAL WALL HEAT TRANSFER

   1         L                 ft        axial length of cylindrical body
   3         r1                in        radius of inside cylindrical surface
   100       h1                Btu/(ft^2 convective coefficient (inside wall)
   33        k1                Btu/(ft*h conductive constant (1st layer)
   3.25      r2                in        radius of intermediate interface
   .051      k2                Btu/(ft*h conductive constant (2nd layer)
   4.25      r3                in        radius of outside surface
   10        h2                Btu/(ft^2 convective coefficient (outside wall)
   .9        epsi                        radiation emissivity (outside wall)
             Q        203.63207 Btu/h      total heat transferred across wall
   300       T0                oF        inside fluid temperature
             T1       298.70364 oF        inside wall temperature
             T2       298.62503 oF        intermediate interface temperature
             T3       128.15089 oF        outside wall temperature
   120       T4                oF        outside environmental temp
             Rh1      .0063662  oF*h/Btu  therm. convect. resistance (inside)
             Rk1      .00038604 oF*h/Btu  therm. conduct. resistance (1st layer)
             Rk2      .83716744 oF*h/Btu  therm. conduct. resistance (2nd layer)
             Rh2      .04493787 oF*h/Btu  therm. convect. resistance (outside)
             Rr       .36632023 oF*h/Btu  therm. radiation resistance (outside)
   1.713E-9  sigma             Btu/(ft^2 Stefan-Boltzmann constant

================================ RULE SHEET ====================================
S Rule ----------------------------------------------------------------------------
  Rh1*h1*2*pi()*r1*L=1
  Rk1*k1*2*pi()*L=ln(r2/r1)
  Rk2*k2*2*pi()*L=ln(r3/r2)
  Rh2*h2*2*pi()*r3*L*conv=conv
  Rr*2*pi()*r3*L*epsi*sigma*(T4^4-T3^4)*rad=rad*(T4-T3)
  Ra=Rh1+Rk1+Rk2
  Rb*(Rh2+Rr)*rad*conv=(Rh2*Rr)*rad*conv  "convection and radiation in parallel
  Rb*(1-rad)*conv=(1-rad)*conv*Rh2        "convection, no radiation
  Rb*(1-conv)*rad=(1-conv)*rad*Rr         "radiation, no convection
  Rb*(1-conv)*(1-rad)=0                   "neither convection nor radiation
  T4=T0-Q*(Ra+Rb)
  T3=T0-Q*Ra
  T2=T0-Q*(Rh1+Rk1)
  T1=T0-Q*Rh1

  rad=sgn(epsi)              "rad=0 if epsi=0, 1 otherwise
  conv=sgn(h2)               "conv=0 if h2=0, 1 otherwise
  (r3-r2)*given('r2,0,1)*given('k2,0,1)=0  "sets r2=r3 if neither r2, k2 given
  (k2-1)*given('r2,0,1)*given('k2,0,1)=0   "sets k2=1 if neither r2, k2 given
```

Thus, the total heat loss per foot of pipe is 203.63207 Btu/h.

# 7. Building Design and Construction

## Stair Design

This model uses proper proportioning techniques to determine the values of riser height, tread depth, total rise and total run necessary for a comfortable staircase.




## Sample Problem 7.1

In this situation we know the height of the room is 8 feet and the thickness of the floor is 10 inches. We have estimated that the risers will be about 7.5 inches high.

## Solution

- Load the model STAIRS
- Enter input values

| | |
|---|---|
| 8*12 + 10 | rise |
| 7.5 | hguess |

- Solve the model

```
==================== VARIABLE SHEET ============================================
St  Input---- Name--- Output--- Unit----- Comment-------------------------------
    106       rise              in        total rise
    7.5       hguess            in        approximate riser height desired
              #riser1 14                  1st alternative for number of risers
              height1 7.5714286 in        1st alternative for riser height
              #riser2 15                  2nd alternative for number of risers
              height2 7.0666667 in        2nd alternative for riser height
              #riser                      actual number of risers
              height            in        actual riser height

              run               in        total run
              #tread                      number of treads
              depth             in        actual depth of tread; run per step
              depth1            in        tread depth from 1st rise-run equation
              depth2            in        tread depth from 2nd rise-run equation
              depth3            in        tread depth from 3rd rise-run equation


============================== RULE SHEET ======================================
S Rule ------------------------------------------------------------------------
      "RISE AND RISERS
  #riser1 = int(rise/hguess)        "   STAIRS.TK determines the values needed
  #riser2 = int(rise/hguess) + 1    "   to create a comfortable staircase.
  height1 = rise/#riser1
  height2 = rise/#riser2
  #riser = rise/height

      "RUN AND TREADS
  #tread = #riser - 1
  run = #tread*depth

      "RISE RUN RELATIONSHIPS FOR COMFORTABLE STAIRS
  2*height + depth1 = 25
  height + depth2 = 17.5
  height*depth3 = 75
```

- Enter input value
  14 #riser.

- Solve the model

```
==================== VARIABLE SHEET ============================================
St  Input---- Name--- Output--- Unit----- Comment-------------------------------
    106       rise              in        total rise
    7.5       hguess            in        approximate riser height desired
              #riser1 14                  1st alternative for number of risers
              height1 7.5714286 in        1st alternative for riser height
              #riser2 15                  2nd alternative for number of risers
              height2 7.0666667 in        2nd alternative for riser height
    14        #riser                      actual number of risers
              height  7.5714286 in        actual riser height

              run               in        total run
              #tread  13                  number of treads
              depth             in        actual depth of tread; run per step
              depth1  9.8571429 in        tread depth from 1st rise-run equation
              depth2  9.9285714 in        tread depth from 2nd rise-run equation
              depth3  9.9056604 in        tread depth from 3rd rise-run equation
```

- Enter input value
  10 depth

- Solve the model

```
==================== VARIABLE SHEET ========================================
St Input-- Name--- Output--- Unit- Comment-------------------------------------
                                   ** STAIR DESIGN **
                                       RISERS
   106     rise              in    total rise
   7.5     hguess            in    approximate riser height desired
           #riser1 14              1st alternate for number of risers
           height1 7.5714286 in    1st alternate for riser height
           #riser2 15              2nd alternate for number of risers
           height2 7.0666667 in    2nd alternate for riser height
   14      #riser                  actual number of risers
           height  7.5714286 in    actual riser height
                                       TREADS
           run     130       in    total run
           #tread  13              number of treads
   10      depth             in    actual depth of tread; run per step
           depth1  9.8571429 in    tread depth from 1st rise-run eq
           depth2  9.9285714 in    tread depth from 2nd rise-run eq
           depth3  9.9056604 in    tread depth from 3rd rise-run eq
```

The above discussion illustrates what happens when a partial set of input values are entered before solving. TK Solver only solves for the output values it can calculate for, given the particular set of input values.

# How to...

## Bring up a sheet

Pressing = is used to display the Rule Sheet, Variable Sheet, or Unit Sheet. You may use the arrow keys to select a sheet or press the first letter in the sheet name ( =V brings up the Variable Sheet).

The Dive (>) command will display the subsheet associated with the current field on the Variable Sheet.

Pressing ; will switch between two sheets which are currently displayed on the screen.

## Blank a variable's value

To blank the input value of a variable, just enter a space in the Input field or press B in the variable's Status field.

## Cancel/Undo

F2 cancels the current command sequence or returns a field to its previous status when you are in editing mode.

## Clear/Blank

The Blank (/B) command blanks the selected fields.

Use /R to reset a variable, a sheet or the entire model.

## Copy

The Copy (/C) command allows the duplication of the contents of selected fields to an alternate location.

## Create a new model

Press /RAY (Reset, All, Yes). The screen resets to its starting condition, with all sheets cleared.

Then type in the new rules.

## Delete/Cut

The Delete (/D) command deletes the selected rules. If a row is deleted, the rows below move up.

## Enter Input Values

Place the cursor in the Input field of the variable that you want to give an input value. To input a value and at the same time move to the next field below, press the down-arrow key following the input value.

## Examine

The Examine (/E) command evaluates an expression or variable. You type the new expression directly after the Examine prompt or copy it (/EC) from the Rule Sheet.

## Guess a variable

The Iterative Solver is launched if the Direct Solver fails to solve the entire model, and at least one of the variables that remains unevaluated is marked as a Guess Variable by having either a G in its Status field or a value assigned in the First Guess field in the Variable Subsheet.

## Insert rows

The Insert Rows (/I) command is used to insert blank rows above the cursor. The rows below the cursor move down to make space. Press Ins to insert a single row.

## Load a model

MiniTK needs to be reset (/RAY) before a new model is loaded, unless two models need to be merged.

The Load (/SL or F3) command loads an existing model from disk. When you press F3, spacebar, Enter a list of MiniTK files on the disk is displayed. To load a file, place the cursor next to that file, using the arrow keys, and press Enter.

## Merging Models

It is possible to load more than one model into MiniTK at a time using the Load command. Use the arrow keys and number the models you would like to load together.

You can also load a new model over the top of an existing model. The contents of the newly loaded file will be appended to the existing sheets. If the models have the same variable names the values from the new model will overwrite the values of the previous one.

## Print

The Print (/P) command is used to print a portion of a sheet or the entire sheet.

## Quit

The Quit (/Q) command ends the MiniTK session after confirmation.

## Reset a model

The Reset (/RAY) command resets the current model.

## Save a model

The Save (/SS or F4) command writes the current model to the file name specified.

MiniTK will display the current name, if any, in the prompt line. To save the model under a different name, edit the old name or type in a new one. The current changes will not be saved to the original model. If the name you choose is already being used by another model, MiniTKwill ask if you want to replace that model with the new file.

The Save (/S) command also contains options which allow you to save a a Unit Sheet or a Variable Sheet as a separate file. This is especially useful for storing sheets to be merged with other models.

## Solve a model

Press F9 to solve.

MiniTK's Direct Solver will not provide you with solutions to problems requiring iteration. To invoke the Iterative Solver, you need to make one of the unknown variables a guess variable and assign it a guess value.

# Family of Products

The following pages describe the UTS product line. For additional information call 1-800-435-7887

UTS Software

# TK Solver Plus

The most powerful engineering and scientific problem solving software on the market.

***Features:***

- Uses rules and relationships as basic building blocks.
- Built-in goalseeking or backsolving.
- Automatic unit conversions.
- Automatic iterative solving.
- Context sensitive help.
- Multiple line, bar, and pie charts.
- Plotter and printer drivers.
- Unlimited expandability.
- Boolean Logic.
- If-Then-Else.
- Over 70 Built-in functions.
- User definable functions

***Benefits:***

- No programming required.
- Set up problems in less than 10 percent of the time it takes using any other method.
- Solve problems backward or forward with no extra effort.
- Optimize designs using backsolving.
- Minimal training time needed.
- Applications are easily shared across many different computer platforms.

***Library of Ready to Use Models***

- Differentiation.
- Integration.
- Differential Equations.
- Algebraic Equations.
- Matrix Algebra.
- Complex Numbers.
- Statistics.
- Curve-Fitting.
- Bessel and Gamma functions.
- 3-D and Contour Graphs.
- Financial Analysis.
- Optimization.

TK Solver Plus is one of the most popular engineering and scientific problem solving tools available. Because of its ease of use, TK Solver Plus is being used to solve problems in almost every field of engineering, science and financial analysis. Problems are solved fast and accurately.

### *Industries Using TK*

Aerospace
Chemicals and Petrochemicals
General Manufacturing
Technical Consultants
Defense Contractors/Sub-Contractors
Financial Services
Real Estate

### *What They are Using it for*

Engineering (CAE/CAM)
- Aerospace
- Agricultural
- Architectural
- Chemical
- Civil
- Electrical
- Food
- Geological
- Industrial
- Mechanical
- Structural

Science and Mathematics
- Chemistry
- Mathematical Analysis
- Physics
- Biological Sciences

Accounting
Business Analysis
Financial Analysis
Statistical Analysis

# Roark & Young on TK

Since 1938, *Roark's Formulas for Stress and Strain* has been the most widely used engineering handbook in the world. Now this entire book (1400 design cases & 5000 formulas) has been computerized using TK Solver Plus.

***You're 20, 50, 100 times as productive when you put down the book and boot up Roark & Young on TK.***

- Analyze many different design alternatives in minutes.
- Backsolve to optimize your design.
- Make plots of deflection, stress, bending moment, shear force, and cross sections at the touch of a key.
- Accomplish superposition of loads.
- Minimal training needed — just follow the menus. You can start solving sophisticated problems immediately.
- No limit on materials you can work with.

***Features:***

- Includes every equation and table in the 6th edition.
- Easy-to-use, menu-driven system. Follows the book by chapter/table/case.
- Built-in material property tables.
- Built-in goalseeking (backsolving).

# Heat Transfer on TK

Nearly every field in engineering — mechanical, electrical, electronic, chemical, you name it — requires solving heat transfer problems. This feature packed system is based on the popular engineering text *Fundamentals of Heat and Mass Transfer* by Incropera and DeWitt.

***Can save you 90% of your design time.***

- Minimal training needed — just follow the menus. You can start solving sophisticated problems immediately.
- No limit on fluids & gases you can work with.
- Analyze many different design alternatives in minutes.
- Backsolve to optimize your design.
- Eliminates need for doing Finite Element Modelling in some cases.
- Provides a good start point if FEM is needed.
- Provides an easy way to solve complex problems.

***Features:***

- Over 200 different topics.
- One- and Two-Dimensional, Steady-State Conduction.
- Transient Conduction.
- Convection; External Flow; Internal Flow; Free Convection.
- Boiling and Condensation.
- Heat Exchangers.
- Radiation.
- Multimode Heat and Mass Transfer.
- Diffusion.

# Gear Design and Manufacturing

Expert system software along with over 60 *TK Solver Plus* models for your immediate use.

The expert system will optimize: center distance, backlash, addendum/dedendum changes (cutter feed), design tooling, check for producibility of gears, minimize weight and much more.

***Lets you reduce manufacturing costs as much as 40%.***

- Save design time up to 80%.
- Reduce noise.
- Increase life.
- Reduce weight.
- Reduce tooling inventory.
- Reduce scrap cost.
- Develop better designs, faster.
- Trouble shoot a design on the fly.
- Develop new designs easily as well as evaluate existing designs.
- Accelerate training of employees.

***Features:***

- External spur & helical gears.
- Internal gears.
- Worm gears.
- Epicyclic gear trains.
- Critical design formulas are right in front of you.
- Generates plots of tooth profiles and gear mesh.

# Educational Programs

UTS offers a wide variety of specialized products, site-license contracts, and discounts to its academic customers.

### *TK College Edition*

This version of *TK Solver Plus* includes all the features of the full version. Program comes with Help Disk and Introduction manual.

### *Exploring Physics*

Includes 50 *TK Solver Plus* models to accompany *College Physics* by Gettys, Keller, and Skove. The Instructor's Manual explains the usage of each model and how best to use it in teaching.

TK Solver Plus is being used by hundreds of universities around the world, and applications have been developed for chemistry, mechanics of materials, aerospace engineering, and mechanical engineering — just to name a few.

# Computerizing Your Design Manuals

*Roark & Young on TK* is a classic example of knowledge management using TK Solver.

Having developed this experience UTS is now helping several leading corporations in using TK to computerize their in-house design manuals and handbooks.

Using TK Solver Plus and the Developer's Tool Kit you can complete such projects in a fraction of the time which would be required otherwise.

### *Custom Development*

UTS can help you define the best strategy and implementation plan for computerizing design manuals. We can even do the entire project for you on a turn-key basis. Please call so we can discuss your needs.

### *Developer's Tool Kit*

Computerize your own design manuals or frequently used handbooks for less than 10 percent of the cost of doing the same job using tools such as FORTRAN, BASIC, Pascal, etc.

UTS Developer's Tool Kit helps you do this quickly and efficiently. It consists of:

- *UTS Menuing System.*
- *TK RunTime.*
- *MathLook.*
- *Developer's Notes.*
- *Enhanced TK Library.*

# Accessories

### *TK SolverPacks*

They're packed with problem-solving power in these seven fields:

- Mechanical Engineering.
- Financial Analysis.
- Building Design and Construction.
- Introductory Science.
- Engineering Calculations.
- Electrical Engineering.
- Unit Conversions.

### *MathLook*

*MathLook* converts TK models into a near Mathematical form. It is quite useful for debugging as well as for report writing purposes. *MathLook* output can be sent to the screen, a file, or to a printer. These files can easily be merged into any word processor document.

Before MathLook

```
-------------- RULE SHEET -----------------

((y+i)/(y-i))^3 = sqrt(sin(a/b))+67/pi()^2
```

After MathLook

```
-------------- RULE SHEET -----------------
```

$$\left[\frac{y + i}{y - i}\right]^3 = \sqrt{\sin\left[\frac{a}{b}\right]} + \frac{67}{\pi^2}$$

### *TK CAD Link*

The *TK/CADLink* provides a smooth, two way pipeline to transport data from AutoCAD to *TK Solver Plus* and back. Once you are in *TK Solver Plus*, a whole new world of problem solving power is in your hands.

# Computer Platforms

*TK Solver Plus* and its applications are available on a wide range of computer systems.

***IBM PC (XT, AT, PS/2) and 100% Compatibles***

***Apple Macintosh***

***VAX/VMS***

***Unix Workstations:***

- IBM AIX/RT
- IBM RISC System 6000
- Sun
- HP/UX
- Apollo

Total file compatibility between platforms allows for easy data exchange and sharing of models between many different computer systems and networks.

# Customer Service

UTS offers one of the best customer support services in the industry.

- Hot line telephone support.
- Mail-in and/or FAX support.
- On-site training.
- Product upgrades.
- Custom development of applications.

# MiniTK Reference Card

## Navigation Commands

| | |
|---|---|
| ↑ | Moves cursor up. |
| ↓ | Moves cursor down. |
| ← | Moves cursor left. |
| → | Moves cursor right. |
| **TAB** | Moves cursor to leftmost field. |
| **Shift TAB** | Moves cursor to rightmost field. |
| **Home** | Moves cursor to top of sheet. |
| **End** | Moves cursor to end of sheet. |
| **PgUp** | Scrolls cursor up N-2 lines. |
| | Displays preceding page in the Help index. |
| **PgDn** | Scrolls cursor down N-2 lines. |
| | Displays next page in the Help index. |

**Note:** N is the number of scrollable lines in the current window.

: Goto command: moves cursor to specified row and column (e.g., `:5s` to go to 5th row of Status field).

= Select command: displays specified sheet in current window:

- `V` Variable
- `R` Rule
- `U` Unit

> Dive command:
>
> Brings up a relevant subsheet in the current window.
>
> Brings up a subdirectory in Disk Index.

< Return command:
>
> Brings back original sheet or subsheet.
>
> Brings back the parent directory in Disk Index.

; Switch command: moves cursor between windows.

## Function Keys

| | | | |
|---|---|---|---|
| **F1** | HELP | **F2** | CANCEL ENTRY |
| **F3** | LOAD FILE | **F4** | SAVE FILE |
| **F5** | EDIT | **F6** | ONE WINDOW |
| **F9** | SOLVE | | |

## Special Keys

| | |
|---|---|
| **Ins** | Inserts one row at current cursor position. |
| **Ctrl-Break** | Cancels current command or entry. |

Universal Technical Systems, Inc.
1220 Rock Street
Rockford, Il 61101
815-963-2220

# MiniTK Reference Card

## Slash Commands

**/W** Window command

1 Unsplits screen, displaying current sheet in a single window (same as F6).

The following options retain the current sheet in the current window and display the selected sheet in the other window:

V Variable Sheet
R Rule Sheet
U Unit Sheet

**/B** Blank command blanks specified range of fields in one column.

**/C** Copy command copies specified range of fields to specified destination.

**/D** Delete command deletes specified range of rows.

**/I** Insert command inserts blank rows at current row.

**/M** Move command moves specified range of rows to specified destination.

**/S** Storage command.

L Loads file with entire model or parts of model, appending contents onto current model, if any (same as F3).
S Saves entire model (same as F4).
V Saves Variable Sheet and Variable Subsheets; saves specified range of rows when called from Variable Sheet.
U Saves Unit Sheet; saves specified range of unit conversions when called from Unit Sheet.
D Deletes specified file(s).

**/P** Print command prints specified range of rows from a sheet.

**/E** Examine command.

V Opens the Prompt/Error line for specifying a variable whose value will be displayed.
E Opens the Prompt/Error line for typing in an expression to be evaluated.
C Copies the contents of a field under the cursor to the Prompt/Error line (so it can be edited and/or evaluated).

**/R** Reset command resets specified portions of TK (must be confirmed):

V Resets variable values.
S Resets current sheet.
A Resets all sheets.

**/Q** Quit command quits TK (must be confirmed).

Universal Technical Systems, Inc.
1220 Rock Street
Rockford, Il 61101
815-963-2220

# MiniTK

UTS

*Universal Technical Software (UK) Ltd.*
TSL House, Freebournes Court Newland Street
Witham, Essex CM8 2BL United Kingdom
44 (0376) 500035 Fax 44 (0376) 500609

UTS

*Universal Technical Systems, Inc.*
1220 Rock Street
Rockford, IL 61101, U.S.A.
(815) 963-2220 Fax (815) 963-8884